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I, ANNA MAIJA EVERETT, ACTING TEAM LEADER EXAMINATION SUPPORT & SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. PQ 1446 for a patent by STEVE CHICK RESEARCH PTY LTD filed on 06 July 1999.

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WITNESS my hand this
Seventeenth day of July 2000

A. M. Everett.

ANNA MAIJA EVERETT
ACTING TEAM LEADER
EXAMINATION SUPPORT & SALES

PRIORITY DOCUMENT

SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

AUSTRALIA

PATENTS ACT 1990

PROVISIONAL SPECIFICATION

FOR THE INVENTION ENTITLED:-

"A PLECTRUM FOR A STRING INSTRUMENT, A TRANSMITTER/RECEIVER ARRANGEMENT AND A SIGNAL PROCESSING APPARATUS"

The invention is described in the following statement:-

The present invention relates to string instruments having a plurality of conductive strings, for example electric guitars. In particular, the present invention relates to a plectrum for use with such string instruments, a transmitter/receiver arrangement adapted for use with the plectrum and a signal processing apparatus also adapted for use with the plectrum.

The invention has been developed primarily for use in digital processing of the audio output from a string instrument and will be described hereinafter with reference to this application. However, it will be appreciated that the invention is not limited to this particular field of use. For example, the triggering signal derived from the present invention can also be used to drive effects other than audio effects, for example lighting effects being synchronised with music played upon the string instrument.

Known techniques for processing an audio signal derived from string instruments are limited by the difficulty of providing an accurate triggering signal to enable event-driven signal processing techniques. Accordingly, most signal processing techniques currently used in real-time with string instruments are continuous in the sense that a signal processing process is not stopped and started on an event basis. Typical audio effect processes such as echo, reverberation, phasing, panning, chorus and flanging are usually continuous in nature since the effect is applied to the audio signal continuously for as long as the effect is desired.

An attempt to provide a triggering signal to enable more sophisticated signal processing is described in US Patent No. 4,235,144. This prior art document discloses a conductive pick connected to a contact sensor which senses conductive contact between the strings of the guitar and the conductive pick. In this arrangement, breaking contact between the pick and the string initiates a special musical effect.

It has been appreciated by the inventor of the present invention however that this prior art arrangement suffers numerous technical defects to the extent that it cannot be

successfully employed to provide a triggering signal reliable enough to enable sophisticated event-driven signal processing. In particular, the inventor of the present invention has discovered that the conductive contact between the string and the prior art conductive pick can be subject to numerous imperfections leading to false triggering. This can be exacerbated by the habit of some string instrument players of resting their pick on the string before actually plucking the string. As the prior art arrangement triggers from the moment when conductive contact between the pick and the string is broken, the imperfect conductive connection can result in false triggering. Other factors leading to imperfect triggering by the prior art arrangement of US Patent No. 4,235,144 include: a string and/or the pick may be tarnished, thereby inhibiting stable conductive contact; the pressure of the pick on the string may not be constant due to the player touching the pick against the string lightly; and larger gauge strings in particular can be vibrating quite vigorously towards and away from the pick, thereby initiating and breaking conductive contact prior to plucking of the string. Whilst this imperfect triggering may suffice for the relatively simple effects outlined in the abovementioned US patent, it has been found by the inventor of the present application not to suffice for slightly more sophisticated triggering such as MIDI triggering, Control Voltage and Gate triggering, in other words, the type of triggering required for the signal processing provided by modern synthesizers.

It is an object of the present invention to overcome or ameliorate at least one of the disadvantages of the prior art, or to provide a useful alternative.

According to a first aspect of the invention there is provided a plectrum for a string instrument having a plurality of conductive strings, said plectrum including:

a non-conductive body defining a gripping portion and a plucking portion; and

a conductive tip protruding just beyond an edge of said plucking portion, an outer surface of said tip being sized so as to fleetingly contact a string of said instrument when said string is plucked by said plucking portion, said tip further being capable of operative

association with electronic monitoring circuitry adapted to provide a triggering signal each time the tip contacts any of said strings.

Preferably the tip is electrically connected to a first wire embedded within the body which is, in turn, electrically connected to a second wire external of the body and extending from a point on the body remote of the plucking portion.

In the preferred embodiment the tip protrudes from an outer edge of the plucking portion by no more than 1mm and the perimeter length of the tip is no greater than 8mm.

According to a second aspect of the invention there is provided a transmitter/receiver arrangement adapted for use with a plectrum as described above, said arrangement including a transmitter having a radio frequency signal generator electrically connectable to said tip such that, when said tip fleetingly connects with said string during plucking, the tip injects a radio frequency signal into the string which is detectable by receiver circuitry being tuned to said radio frequency signal, said receiver circuitry being operatively associated with said electronic monitoring circuitry so as to provide said triggering signal.

Preferably the transmitter is mountable to a person playing the instrument, for example by means of a strap mounted to the wrist of the person. The transmitter is preferably electrically connectable to the plectrum by the second wire.

According to a third aspect of the invention there is provided a transmitter adapted for use with a plectrum as described above, said transmitter having a radio frequency signal generator electrically connectable to said tip such that, when said tip fleetingly connects with said string during plucking, the tip injects a radio frequency signal into the string.

According to a fourth aspect of the invention there is provided a receiver adapted for use with the transmitter as described above including receiver circuitry being tuned to said radio frequency so as to detect the radio frequency signal injected into the string, the

receiver being operatively associated with said electronic monitoring circuitry so as to provide said triggering signal.

According to another aspect of the invention there is provided a signal processing apparatus adapted to process an audio signal derived from a string instrument having a plurality of conductive strings being plucked by the plectrum described above, said apparatus including:

a first input to receive said audio signal;

a second input to receive a triggering signal which includes a plurality of triggering pulses, each indicative of a plucking of any of said strings by said plectrum tip;

signal processing circuitry adapted to perform a plurality of different processes, each process modifying the audio signal, said circuitry being electrically connected to said first and second inputs, and wherein said signal processing circuitry is adapted to vary the particular process used to modify the audio signal according to a predefined relationship with said triggering signal; and

an output electrically connected to said signal processing circuitry for outputting a modified audio signal.

In one preferred embodiment the predefined relationship is such that the process is varied each time an integral number of triggering pulses are received. For example, this integral number may be 1, in other words the process applied to the audio signal is varied each time a triggering pulse is received.

A preferred embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Fig. 1 is a cross-sectional view of a plectrum according to the invention taken through Line 1-1 of Fig. 3;

Fig. 2 is a plan view of the plectrum shown in Fig. 1;

Fig. 2a is an exploded view of the tip shown within the dotted region of Fig. 2;

Fig. 3 is a side view of the plectrum shown in Fig. 1;

Fig. 4 is a plan view of the plectrum shown in Fig. 1, along with a string of an instrument;

Fig. 5 is a progressive view of a plectrum according to the present invention plucking a string on an instrument, along a pulse arising from said plucking action;

Fig. 6 is a schematic view of a transmitter/receiver arrangement according to the present invention and its relationship to a string instrument;

Fig. 7 is a plan view of a transmitter mounted to the wrist of a user, said transmitter being electrically connected to a plectrum according to the invention;

Fig. 8 is a part-perspective, part-schematic view of a receiver according to the present invention, the receiver being electrically connected to a string instrument;

Fig. 9 is a circuit diagram showing circuitry included in a transmitter according to the present invention;

Fig. 10 is a circuit diagram showing circuitry included in a receiver according to the present invention;

Figs. 11 to 15 inclusive are waveform diagrams showing various signals associated with the transmitter/receiver arrangement of the present invention;

Fig. 16 is a schematic diagram illustrating the transition between various events in a signal processing apparatus according to the invention; and

Fig. 17 is a schematic view of a signal processing apparatus according to the present invention.

Referring to the drawings, the plectrum 4 shown in Figs. 1 to 5 includes a non-conductive body 5 having a gripping portion 6 and a plucking portion 7. The body 5 is constructive of a plastics material in the preferred embodiment. A conductive tip 8 protrudes just beyond an edge 9 of the plucking portion 7. The outer surface of the tip 8 is sized so as to fleetingly contact a string 10 of the instrument 11 as the string 10 is

plucked by the plucking portion 7. This is best shown in the progressive plucking action illustrated in Fig. 5. In particular, contact between the tip 8 and the string 10 occurs at step D of Fig. 5. The tip 8 is capable of operative association with electronic monitoring circuitry 12, an embodiment of which is shown in Fig. 10. The details of the operative association between the tip 8 and the electronic monitoring circuitry 12 will be described in more detail later in this document. The electronic monitoring circuitry 12 is adapted to provide a triggering signal shown as signal G in Fig. 15 each time the tip 8 contacts any of the strings 10 of the instrument 11.

This inventive arrangement has been found to provide far more reliable triggering than that provided by the prior art. Additionally, because the tip 8 only contacts the string 10 during the instant of plucking, it is possible for the electronic monitoring circuitry 12 to monitor for any moment that conductive contact between the tip 8 and the wire 10 is made, rather than monitoring for the moment when conductive contact is broken, as in the prior art.

The geometry of the non-conductive body 5 and the barely exposed tip 8 is such that a player can rest the plectrum against a string, as shown in views B and C of Fig. 5 prior to plucking without the tip 8 contacting the string 10, and therefore without causing any false triggering. Additionally, as the electronic monitoring circuitry 12 of the preferred embodiment monitors for the instant that conductive contact is made, rather than broken, it is possible for the arrangement of the present invention to provide a triggering signal wherein each triggering pulse is initiated an instantaneous moment before a string 10 is actually plucked. This advantageously effectively provides a lead time which can be offset against any lag time that may exist in the audio signal processing apparatus to help ensure that the audio signal processing apparatus is in a required state prior to, or at the moment of, receiving the audio input resulting from the plucking of the string.

The tip 8 is electrically connected to a first wire 13 which may be embedded within the body 5. In other embodiments (not illustrated), the tip 8 is an integral part of the wire 13. The first wire 13 is, in turn, electrically connected to a second wire 14 external of the body 5. The second wire 14 extends from a point 15 of the body 5 remote of the plucking portion 7.

The tip 8 preferably protrudes from the outer edge 9 of the plucking portion 7 by no more than 1mm. In the preferred embodiment, the distance by which the tip 8 protrudes is 0.5mm. This dimension can be best appreciated with reference to Fig. 3 and in particular to the perpendicular distance separating lines 16 marked thereon. In the preferred embodiment the perimeter length of the tip 8 is no greater than 8mm and the dimension used in the preferred embodiment is 2mm. This dimension can be best appreciated from Fig. 2a, and in particular from the distance separating lines 17 marked thereon. The width of the tip 8 is preferably no greater than the width of the pick and in the preferred embodiment is 0.5mm. This can be best seen with reference to Fig. 3 and in particular to the perpendicular distance separating lines 18 marked thereon. This dimension is less than the corresponding width of the body 5. An outer edge 22 of the tip 8 is shaped to generally correspond to the shape of the outer edge of the plucking region 7 from which the tip 8 extends.

As best shown in Fig. 2, the body 5 of the plectrum 4 is generally a triangular shape. The region adjacent first apex 19 defines the plucking portion 7 and the tip 8 is disposed at the first apex 19. The second wire 14 extends from, or adjacent to, one of the other apexes, in this case, apex 20. In other embodiments, the second wire 14 extends from other regions of the body 5 of the plectrum 4. The region adjacent apexes 20 and 21 defines the gripping portion 6.

The electronic monitoring circuitry 12 is adapted to detect the initiation of conductive contact between the tip 8 and the string 10 and to use said contact as the basis for the

triggering signal. The switch which is effectively formed by the plectrum 4 and the string 10 is shown in an open state in figure 4.

Fig. 6 depicts a schematic representation of the transmitter 23, a receiver 24 and a preferred embodiment of a transmitter/receiver arrangement whereby said transmitter 23 communicates to said receiver 24. The transmitter 23 includes a radio frequency signal generator 25 which is electrically connectable to the tip 8. In one embodiment, the tip 8 is connected to the radio frequency signal generator 25 via the first and second wires, the second wire terminating in a plug which is mateable with a socket provided upon the transmitter 23. When the tip 8 fleetingly connects with the string 10 during plucking, as shown in Fig. 5, the tip 8 injects a radio frequency signal shown as signal A in Fig. 11 into the string 10. The radio frequency signal (signal A) is detectable by receiver circuitry 26 which is tuned to the signal. The receiver 24 is operatively associated with electronic monitoring circuitry 12 so as to provide the triggering signal (signal G).

In the illustrated preferred embodiment the transmitter 23 is mountable to a person 27 playing the instrument 11. In particular, the transmitter 23 is disposed upon, or housed within, a strap 28 mountable to a wrist of the person 27. The strap 28 includes means to house or mount a battery (not illustrated) to power the radio frequency signal generator 25. This allows the player 27 of the instrument 11 greater freedom of movement as compared to having the plectrum 4 hard wired to circuitry win the receiver which would require a long cable from the plectrum to the receiver.

The strings 10 of the instrument 11 are electrically connected to an instrument-ground 29, which is, in turn, electrically connected to the receiver 24, and in particular to the receiver circuitry 26. The instrument-ground 29 is normally included as a part of the audio cable.

The radio frequency generator 25 is capable of producing a signal A as shown in Fig. 11. This signal is a waveform at a carrier frequency which preferably lies within the range of 100KHz to 30MHz, and in the preferred embodiment is 3.545MHz.

As best shown in Fig. 6, the instrument-ground 29 is electrically connected to the receiver-ground 30, the connection 31 effectively forming an electrical short between the grounds 29 and 30 at audio frequencies such as those generated by the instrument 11, however the connection 31 also effectively forms a first tuned receiver between the grounds 29 and 30, the tuned receiver being broadly tuned at the carrier frequency. The connection 31 is an inductor (labelled L1 in Fig. 6 and labelled L11 in Fig. 10) and a capacitor (labelled C1 in Fig. 6 and C26 in Fig. 10) wired in parallel between the instrument-ground 29 and the receiver-ground 30. The 3.545MHz radio frequency that is coupled into the resonate circuit 31 appears as a voltage at connection 29, this voltage is illustrated in Fig. 12 signal B. Signal B is coupled through the capacitor C27 into the amplifier circuitry 28 which is comprised of Q1, R34, R35, R36, R37 and C23. This 3.545MHz amplified signal is then coupled through C22 onto the base of transistor Q3 which forms a non-linear mixer along with R42, R38, R39, and R43, circuitry 34. A 4.00MHz local oscillator signal is derived from the microprocessor's clock circuit and coupled through the capacitor C29 into the circuitry 33. This circuitry comprises of Q2, C29, R41, R45 and R40 and is an emitter follower buffer amplifier for the 4.00MHz local oscillator signal. The output of Q2 is then coupled onto the emitter of Q3 through the capacitor C34. The resulting Signal C as appears on the collector of Q3 has a frequency component that is equal to the difference between the 3.545MHz carrier frequency and the 4.00MHz local oscillator. This difference is known as the intermediate frequency and in the preferred embodiment is a waveform having a 455KHz component as shown in Fig. 13. The amplitude of the 455KHz frequency component is directly proportional to the amplitude of the 3.545MHz carrier radio frequency. The band pass filter as described

next selectively passes only the 455KHz frequency so in effect the circuitry has selectivity for the frequency of 3.545MHz. This helps in the rejection of broad spectrum noise which could potentially interfere with the operation of the device. This technique is known as a superheterodyne receiver. This gives Signal C as shown in Fig. 13. Signal C is then passed through a selective band pass filter 35 tuned at the intermediate frequency. In the preferred embodiment, the selective band pass filter 35 is comprised of a ceramic resonator labelled X2 in Fig. 10. The output of the selective band pass filter 35 is signal D as shown in Fig. 14. Signal D is present in the electronic monitoring circuit only when the tip 8 of the plectrum 4 is in contact with the string 10. This is shown in Fig. 15 where intermittent bursts of signal D are shown.

The signal is then amplified by Q4 as shown in Fig. 10 and passed through a detector circuit 36 which is made up of Q5, R50 & C42 as also shown in Fig. 10. The output of Q5 is the envelope of the intermediate frequency component which is proportional to the radio frequency signal. This is shown as signal E in Fig. 15. The envelope has brief pulses 37 which substantially correspond to the period of time for which the plectrum tip 8 is in contact with the string 10. This signal is then AC coupled and amplified by U5B as shown in Fig. 10. The brief pulses 37 are then time-stretched so as to provide a modified signal (signal F shown in Fig. 15) having time-stretched pulses 38 which, because of their longer duration, are not missed by the microprocessor to which the signal is subsequently fed. The time-stretching of the pulses 37 is performed by D15, C45, R54 and R57 as shown in Fig. 10.

The electronic monitoring circuitry 12 includes a microprocessor 39 adapted to receive said modified signal (signal F) and to perform an analogue-to-digital conversion thereto using U2 so as to produce a digital representation of signal F. The microprocessor 39 is further adapted to detect positive transients 40 in the digital version of the signal and to generate a triggering signal (signal G) by correlating each of the

positive transients 40 with an initial contact of the plectrum tip 8 with the string 10. In other words, each time the plectrum tip 8 initially makes conductive contact with the string 10, instantaneously before the moment of plucking, the electronic monitoring circuitry is adapted to output a triggering signal responsive to said contact. The triggering signal (signal G) provided by one preferred embodiment of the invention is of the MIDI (Musical Instrument Digital Interface) type. An alternative embodiment outputs a triggering signal consisting of a control voltage and a gate signal (this alternative triggering signal is not illustrated). The triggering signal is fed from the receiver 24 via triggering cable 41 as shown in Fig. 8.

Put simply, when a transient 40 of sufficient amplitude is detected, a pick event is deemed to have happened and the associated controlled signals are then generated to provide a triggering signal.

The audio signal (not illustrated) generated by the instrument 11 is applied to amplifier U3C via resistor R13 as shown in Fig. 10. This circuitry 50 is adapted to store maximum amplitudes of the audio signal from the instrument 11. In other words, each time a string 10 of the instrument 11 is plucked, the receiver circuitry stores a maximum amplitude of the resulting audio signal. The circuitry of U3B, U3D, D4, D7 and C15 (as indicated on Fig. 10) holds said maximum amplitude. The electronic monitoring circuitry 12 includes a microprocessor 39 (which may be the same microprocessor mentioned previously, or may be a separate microprocessor) which is adapted to measure the stored amplitude and to output a value corresponding to the amplitude. In some embodiments this value is digital and in other embodiments it is analogue. The value is effectively an output corresponding to the force with which the string 10 is plucked. This information can be transmitted to an audio effects system so that effects can respond to the intensity with which a string 10 is plucked. In some embodiments, the electronic monitoring circuitry 12 and the receiver circuitry 50 are adapted to measure and record the maximum

amplitude of the audio signal each time the tip 8 contacts a string 10. In other embodiments, circuitry 12 and 50 is adapted to measure the maximum amplitudes occurring during predefined time intervals.

With reference to Fig. 17, the signal processing apparatus 42 processes the audio signal derived from the string instrument 11. In some preferred embodiments all signal processing is performed digitally, in other preferred embodiments the signal processing may be exclusively analogue, or a combination of digital and analogue. The signal processing apparatus 42 is adapted to function in conjunction with the plectrum of the present invention. The apparatus 42 includes a first input 43 to receive the audio signal from the string instrument 11. The second input 44 receives the triggering signal (signal G) which includes a plurality of triggering pulses, each indicative of a plucking of any of the strings 10 by the plectrum tip 8. The apparatus 42 houses signal processing circuitry 45 which is adapted to perform a plurality of different processes, each process modifying the audio signal. For example, some of the processes may be relatively straight forward modifications to provide effects such as echo, reverberation, phasing, panning, chorus and flanging. However more sophisticated and elaborate processes may be provided by altering one more parameter values and/or one or more effects algorithms which are, in turn, used by the signal processing circuitry 45 to modify the audio signal. The signal processing circuitry 45 is electrically connected via wires 46 to the first and second inputs respectively, 43 and 44. The signal processing circuitry 45 is adapted to vary the particular process used to modify the audio signal according to a predefined relationship with the triggering signal. In other words, the signal processing circuitry 45 has a number of different processes or "effects", which can be varied based upon the triggering signal. The apparatus 42 also includes an output 47 electrically connected to the digital signal processing circuitry 45 via wire 46 for outputting the modified audio signal (not illustrated).

The predefined relationship between the triggering signal and the varying of the particular process used to modify the audio signal can be adjusted as required. For example, in one embodiment, the particular process used to modify the audio signal is varied each time an integral number of triggering pulses are received. In another embodiment, the integral number is 1, meaning that the particular process used to modify the audio signal is varied each time a triggering pulse is received by the signal processing circuitry 45. This is shown schematically in figure 16. It would be appreciated by those skilled in the art, however, that other predefined relationships may be used, for example making a first variation to the particular process after a first number of triggering pulses are received, followed by a second variation to the particular process after a second number of triggering pulses are received, and so on.

During the transition from a first process to a second process, the first process is progressively faded out and the second process is simultaneously progressively faded in. This transitional arrangement is illustrated in Fig. 16 where the horizontal axis represents time and the vertical axis represents the degree to which a particular process is used to modify the audio signal. At the time when a triggering pulse is received 48, the degree to which the first process 49 is applied to the audio signal begins to decrease and, simultaneously, the degree to which the second process 50 is applied to the audio signal is increased. This provides a smooth transition between processes. As can be seen in Fig. 16, the same fade-in, fade-out technique is used each time a subsequent variation of a process is made. The transition commences upon receipt of a triggering pulse such that each transition is initiated substantially at each moment the tip 8 first contacts the plectrum during plucking. As described above, triggering from the moment of initial contact (rather than the moment of which contact is broken as in the prior art) advantageously provides a brief lead-in time before the string 10 of the instrument 11 is

actually plucked. This enables any delay that may be introduced by the signal processing circuitry 45 to be off-set against the "head start" provided by the triggering signal.

The preferred embodiment of the signal processing apparatus 42 includes provision for at least one of the operative characteristics of one or more of said processes to be variable dependent upon the maximum amplitude of the audio signal each time the plectrum 4 contacts a string 10. The signal processing apparatus 42 includes a third input 51 to receive a value indicative of a maximum amplitude of the audio signal from the microprocessor 39. The third input 51 is adapted to feed the value to the signal processing circuitry 35 via a wire 52. The operative characteristics of the processes which may be varied include factors such as the parameters and/or the algorithms used to modify the audio signal. In some embodiments, the function of the second and third inputs, 44 and 51, is performed by a single input (not illustrated) which is adapted to receive and de-code an information stream having information relating to both the triggering and the maximum amplitude.

Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

DATED this 6th day of July, 1999

STEVE CHICK RESEARCH PTY LIMITED

Attorney: PETER R. HEATHCOTE
Fellow Institute of Patent Attorneys of Australia
of BALDWIN SHELSTON WATERS

Fig 1

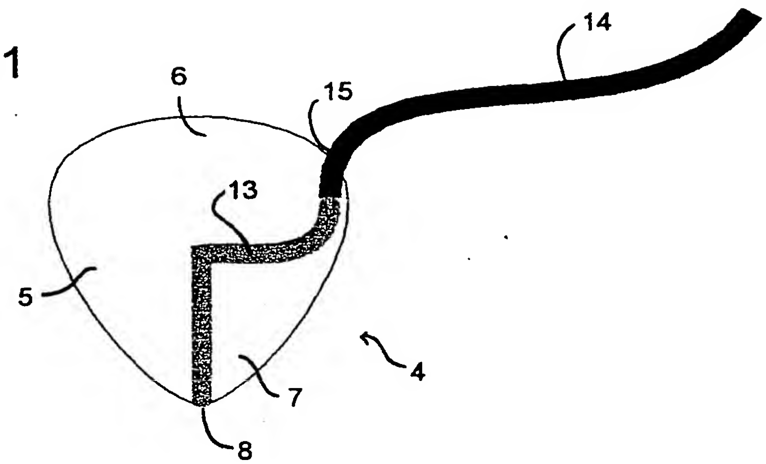
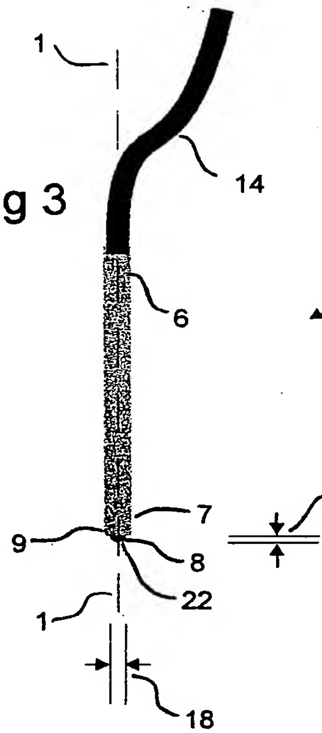


Fig 3



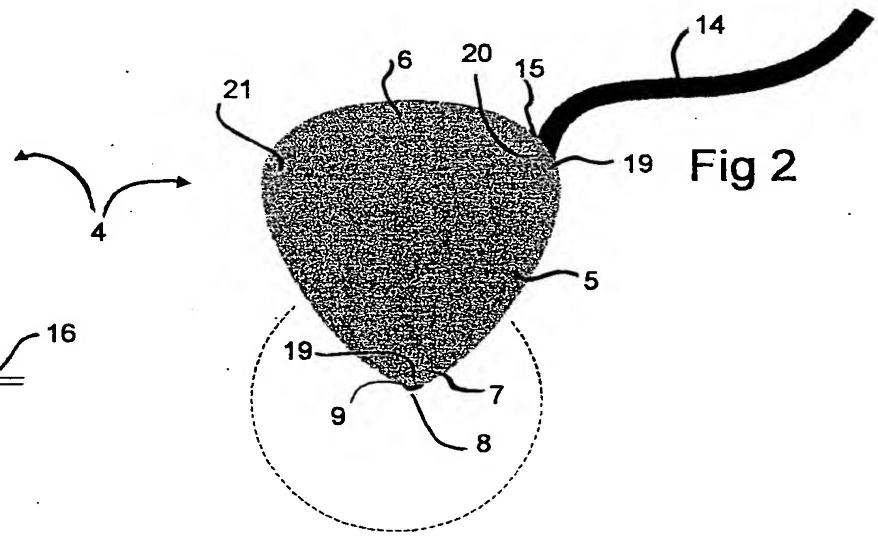


Fig 2

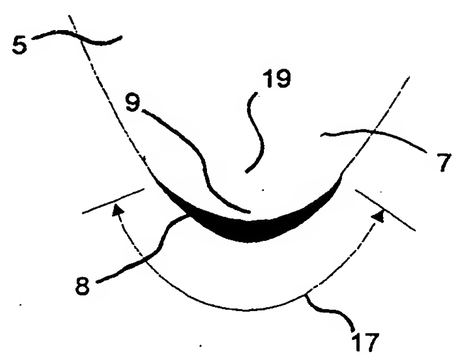


Fig 2A

Fig 4

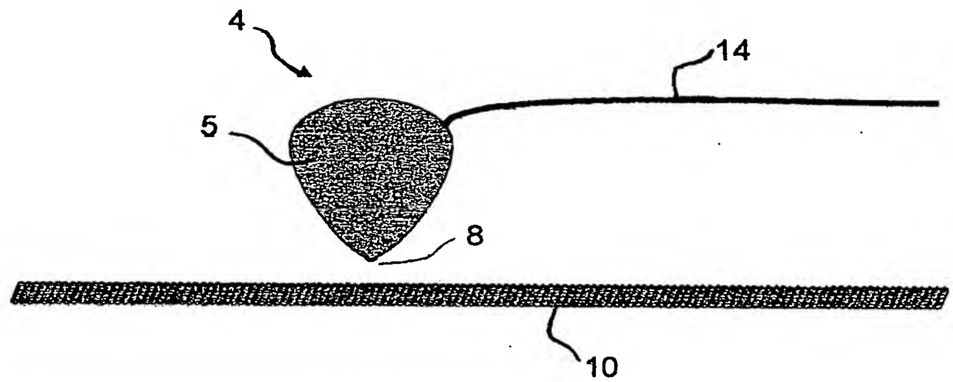
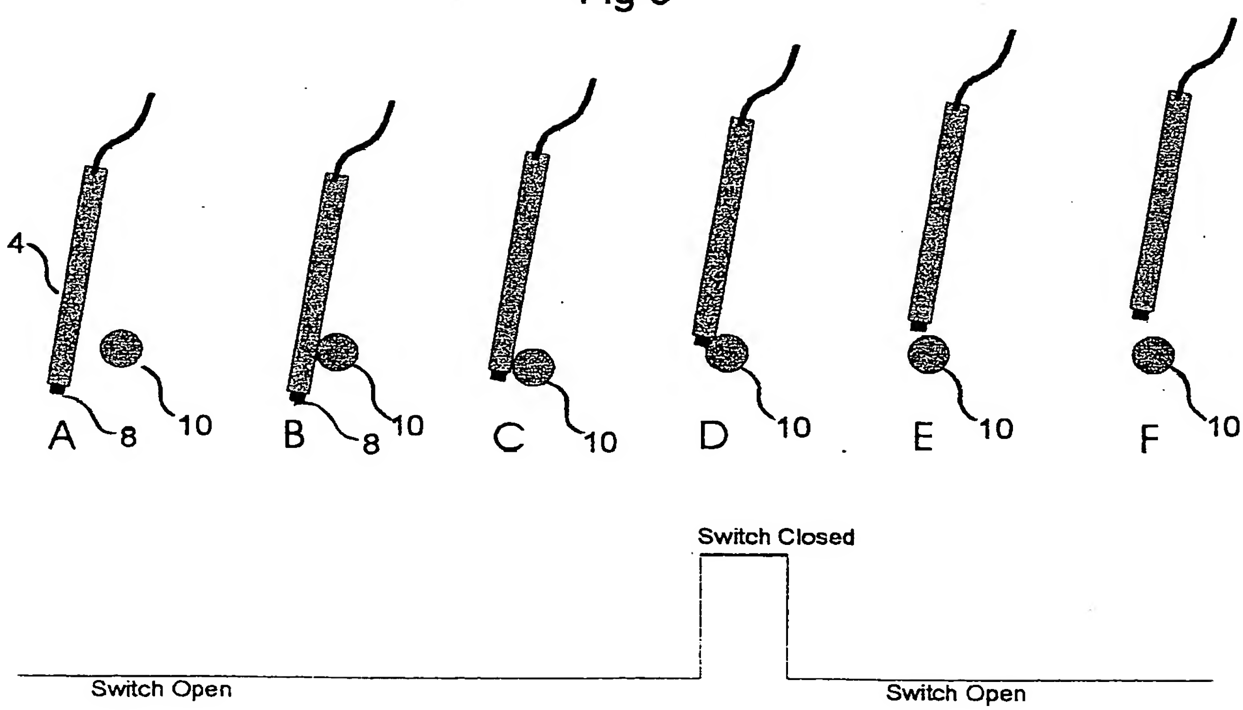

4
14
5
8
10

Fig 5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B
8
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C
10
D
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E
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F
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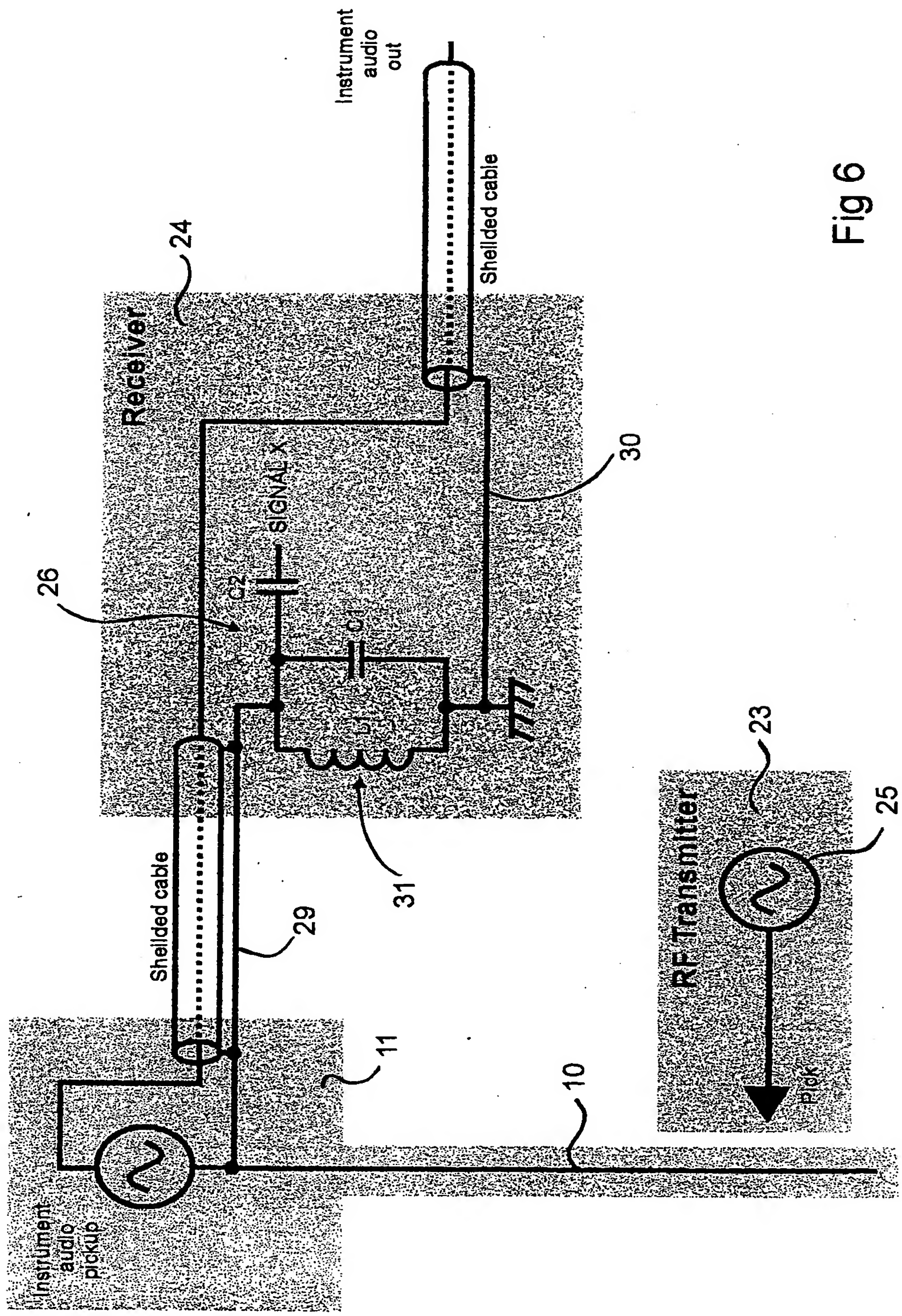
Switch Open
Switch Open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Shellded cable
Receiver
24
SIGNAL X
C2
C1
L1
26
30
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29
Shellded cable
11
10
Instrument audio pickup
RF Transmitter
23
25
Pick

Fig 6

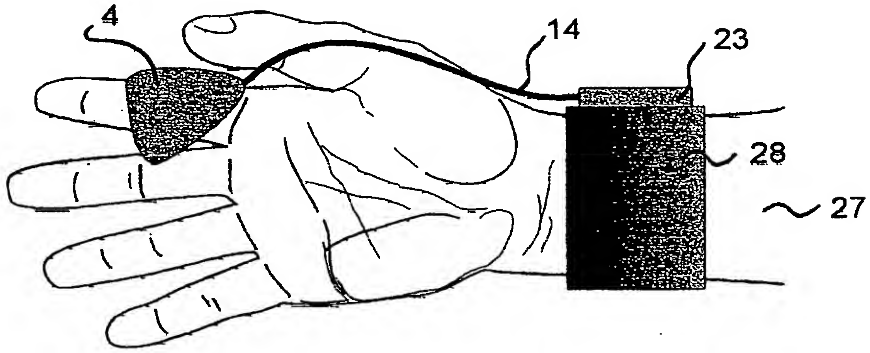


Fig 7

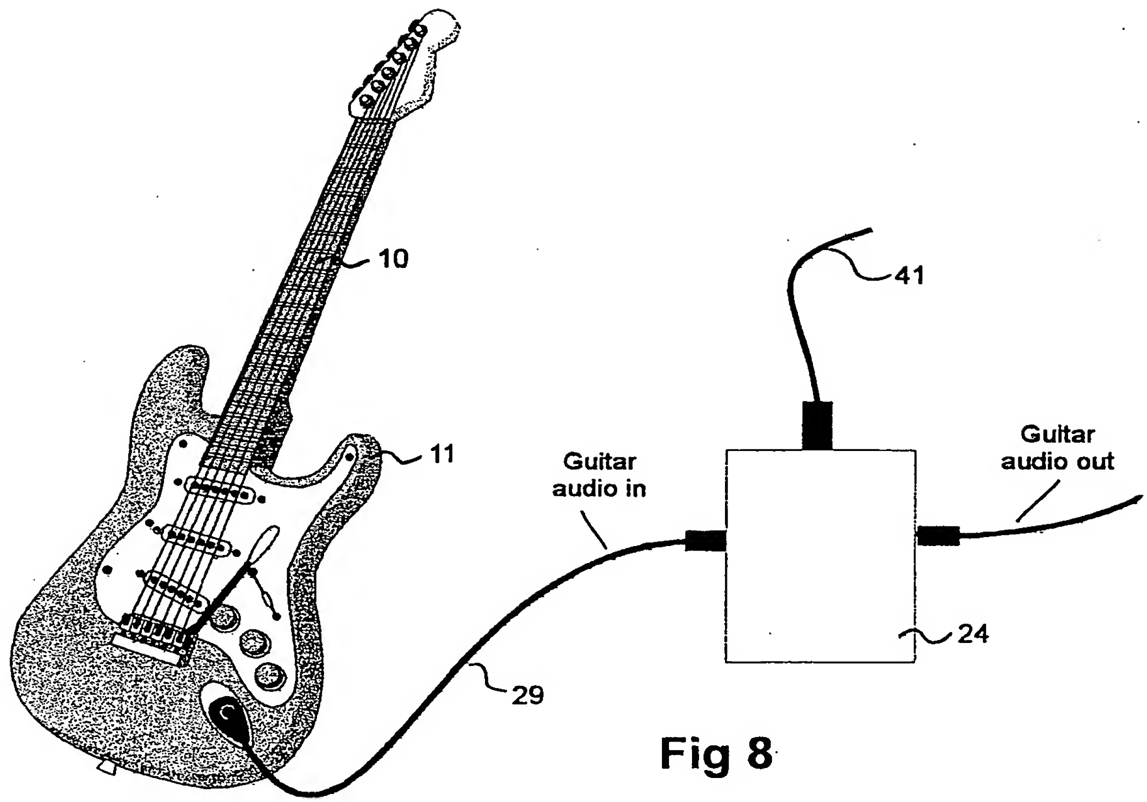
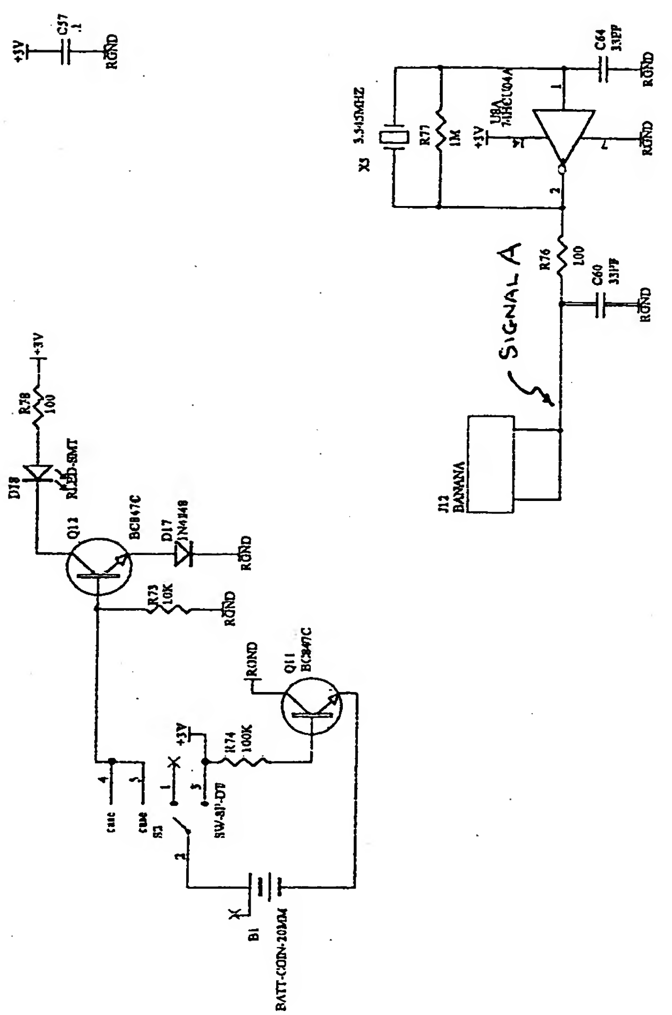


Fig 8

Fig 9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100K
Q11
BC847C
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C57
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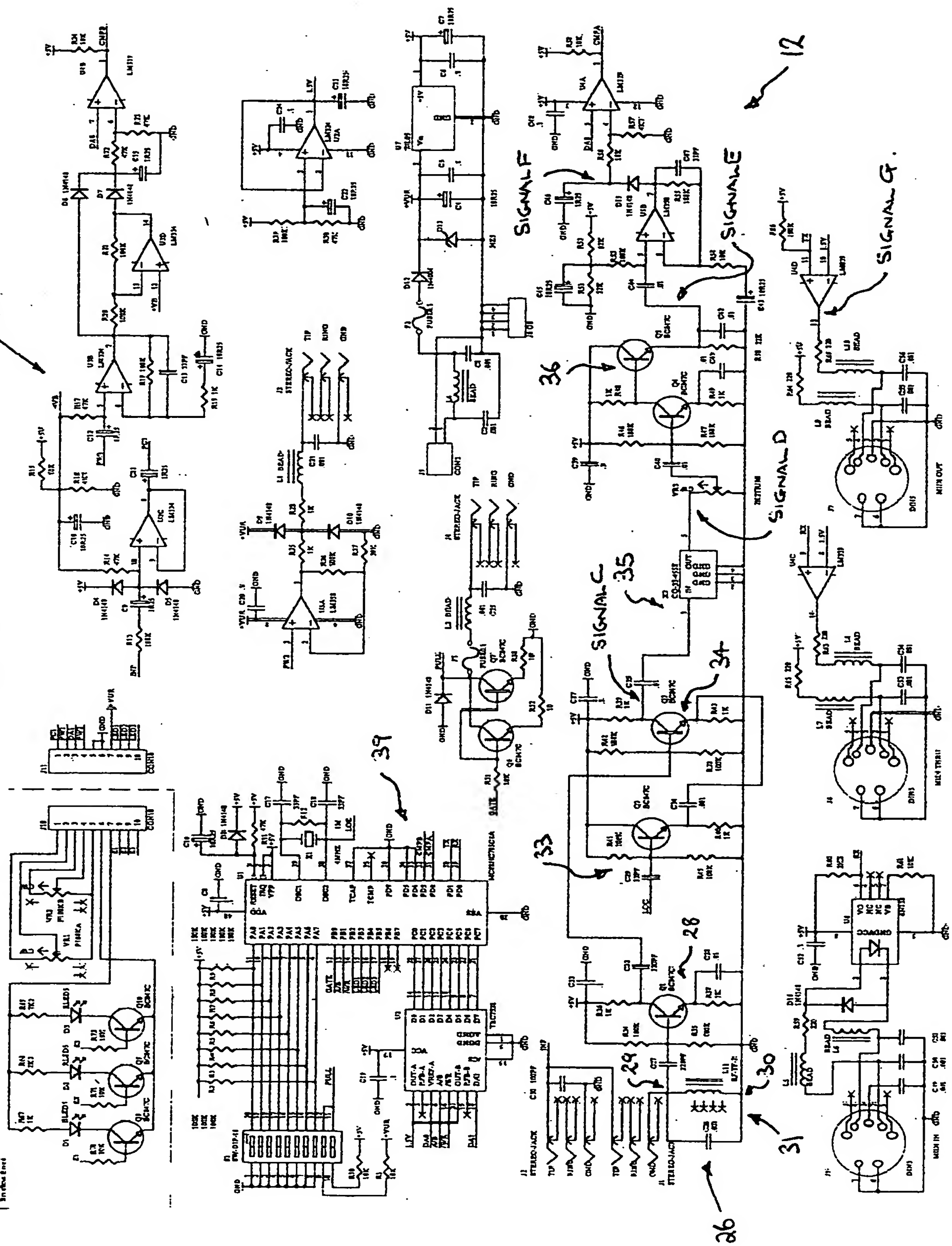
B1
BATT-COIN-20MM
SW-SP-DT
S2

Fig 10


12
50
SIGNAL F
SIGNAL E
SIGNAL G
SIGNAL D
SIGNAL C
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35
34
39
33
28
29
30
31
26

Fig 11

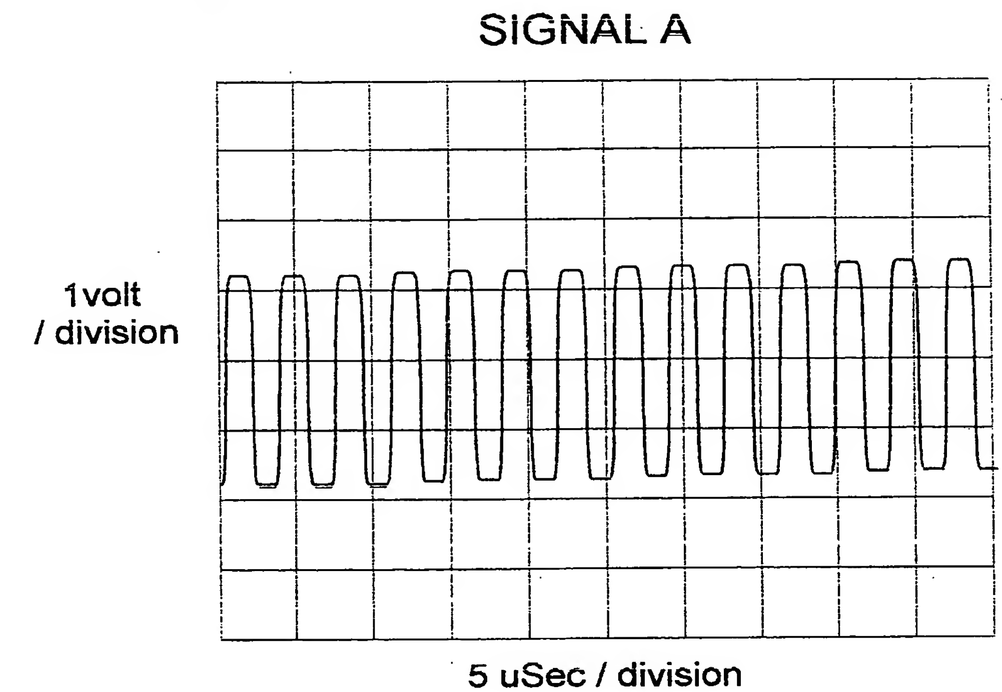

SIGNAL A
1volt
/ division
5 uSec / division

Fig 12

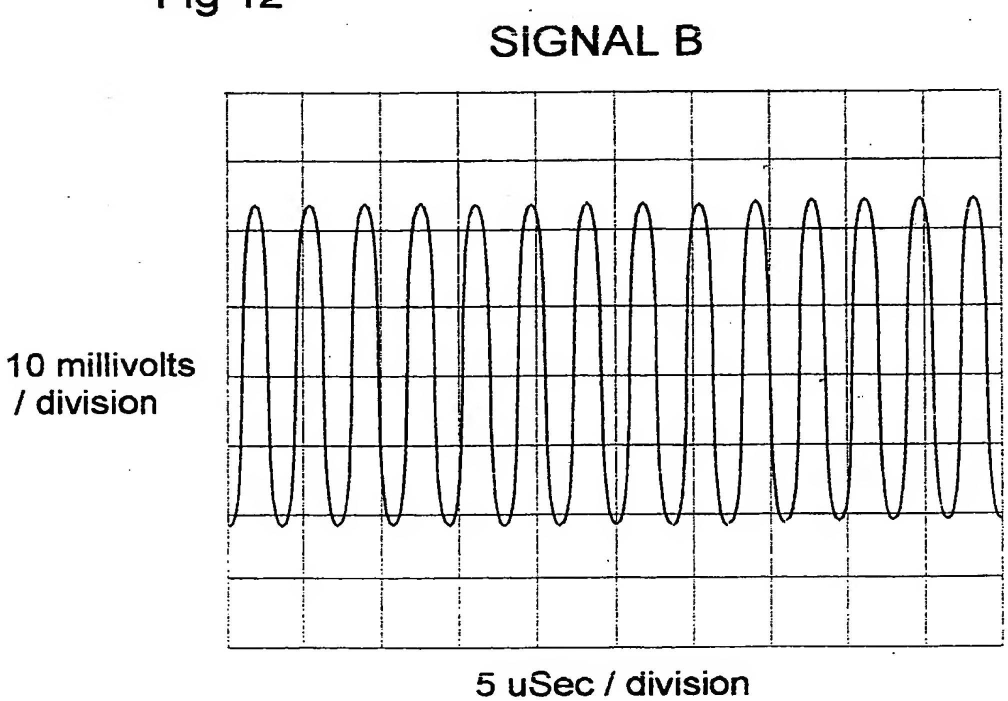
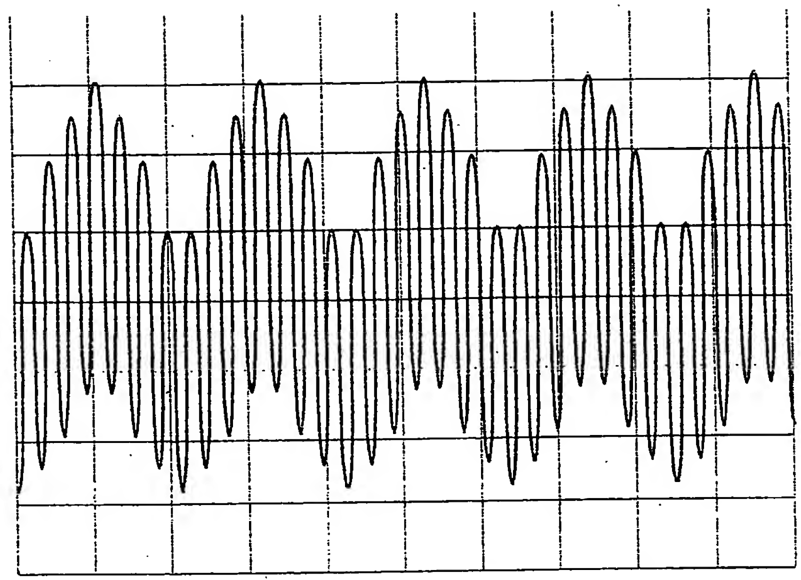

SIGNAL B
10 millivolts
/ division
5 uSec / division

Fig 13

SIGNAL C

20 millivolts / division

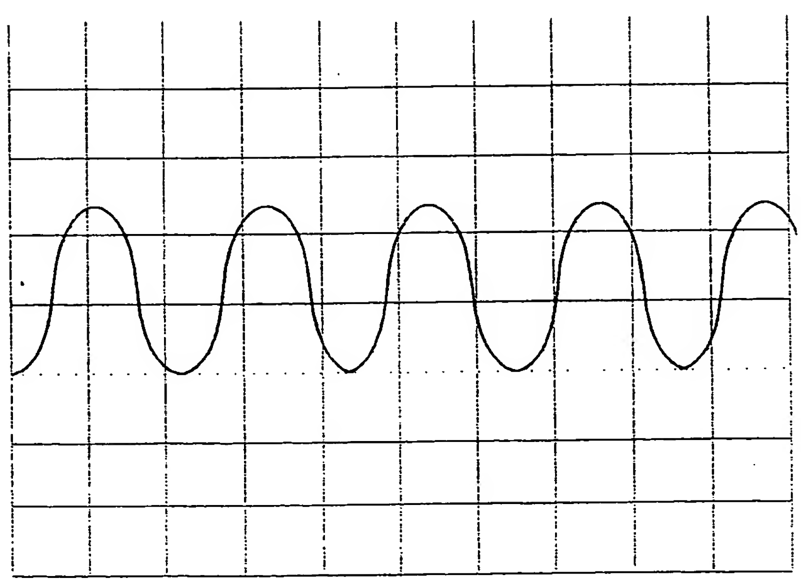


0.5 uSec / division

Fig 14

SIGNAL D

20 millivolts / division



0.5 uSec / division

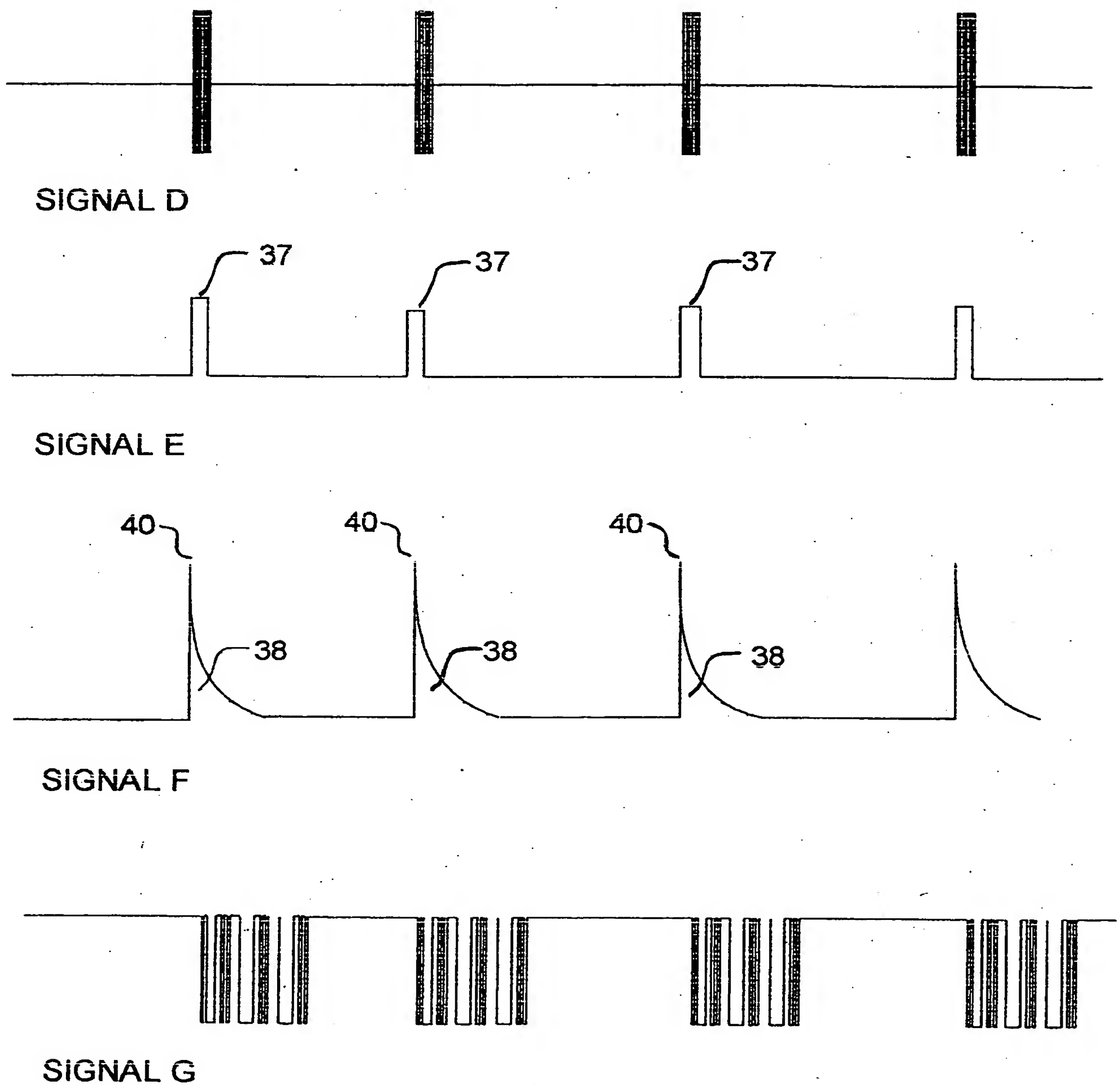


Fig 15

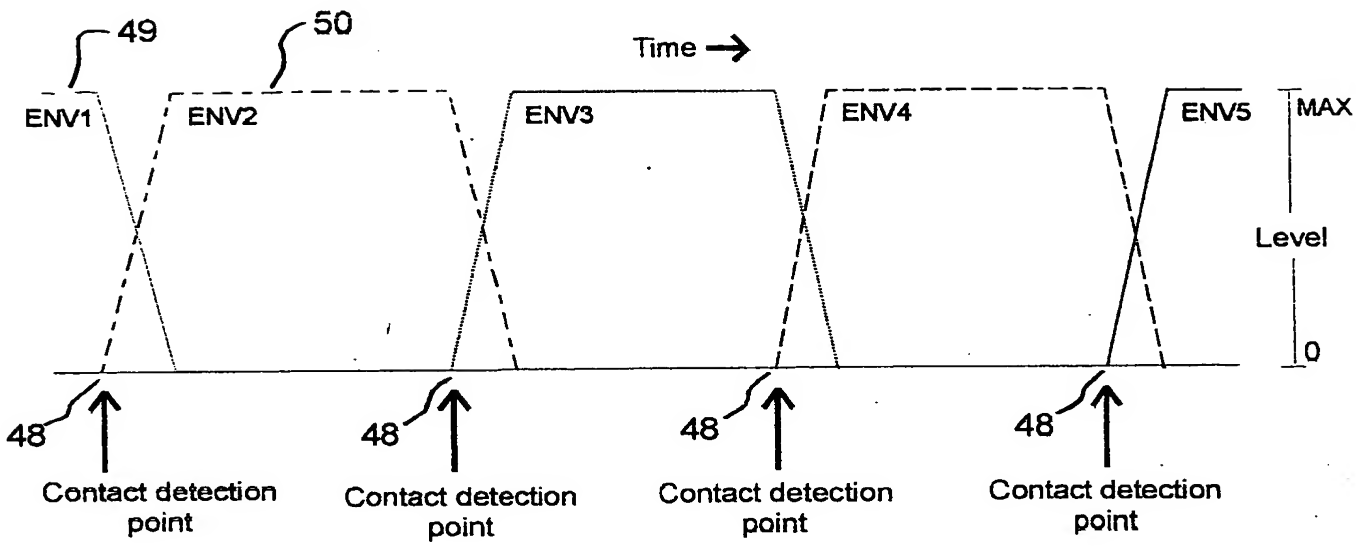

49
50
Time →
ENV1
ENV2
ENV3
ENV4
ENV5
MAX
Level
0
48
Contact detection point
48
Contact detection point
48
Contact detection point
48
Contact detection point

Fig 16

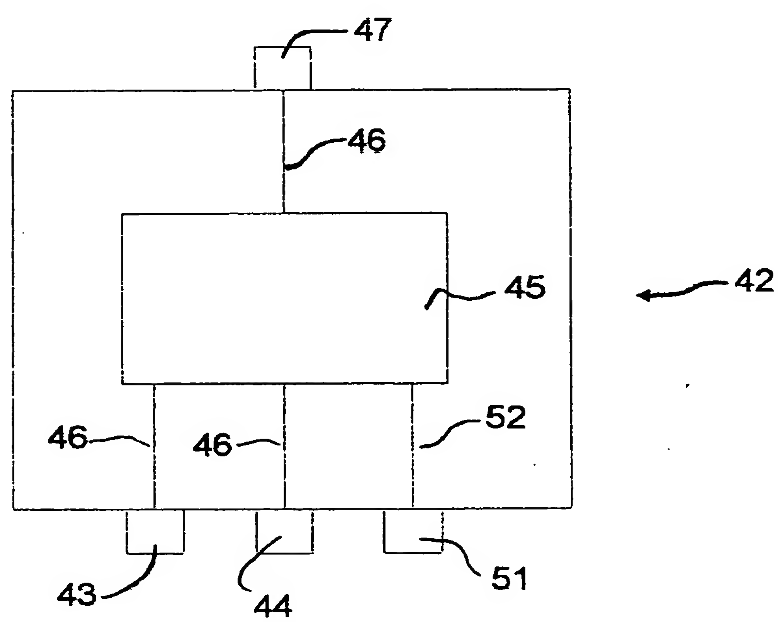

47
46
45
42
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Fig 17